MEMORANDUM

To: Debra Perkins-Smith and Joe Hart, David Evans and Associates

From: Jeffrey Ang-Olson and Sergio Ostria, ICF Consulting

Date: November 19, 2003

Re: US 2 EIS – Benefit Cost Analysis of Alternatives, Revised
PLH-TCSP 1-6(44)384, C.N. 4951--US 2, Havre to Fort Belknap

This memo describes a benefit cost analysis of the alternatives under consideration for the US 2, Havre to Fort Belknap environmental impact statement (EIS). The analysis of economic impacts is a two-step process. Step 1 identifies the existing economic baseline conditions and evaluates the potential to promote economic development in the study area through improvements to the US 2 study segment, as described in the *Existing Economic Conditions Report* dated June 2003. The second step in the analysis process, described in this memo, is an evaluation of the economic efficiency of the proposed project alternatives for the US 2 segment.

Benefit-cost analysis is a tool used to evaluate public expenditure decisions. The analysis involves identifying and quantifying all the benefits and costs that will accrue to society if a project is undertaken. For transportation projects, this involves estimating a dollar value for benefits to users of the facility such as reduced accidents, vehicle operating costs, and travel time, and comparing these benefits to project costs such as construction, operations, and maintenance expenditures. Total costs are subtracted from total benefits to calculate net benefit.

When enumerating benefits in a benefit-cost analysis framework, care must be taken to count only real increases in national output and welfare. Thus, reductions in travel time or accidents are counted as benefits because they are not offset by any losses elsewhere. The impact of construction on the local economy is not counted as a benefit because it does not change the underlying productivity of the local economy. Any increase in local economic activity would be considered a transfer, offset elsewhere by a reduction in economic activity due to the taxes necessary to fund the project. Similarly, the benefit-cost analysis does not explicitly count non-user benefits if they are assumed to be captured in the value of the user benefits. For example, the benefits to a business of reduced freight or commuter travel times are assumed to be captured in the commercial and passenger vehicle travel time benefits. For an examination of potential economic development benefits, refer to the *Existing Economic Conditions Report*.

StratBENCOST Model Overview

The StratBENCOST model was used to perform the benefit-cost analysis. StratBENCOST was originally developed in 1996 for the Transportation Research Board and is widely used by state departments of

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transportation and metropolitan planning organizations to assist in transportation planning and project decision making efforts.[1] The model can be used to analyze a variety of highway projects, including:

- resurface/rehabilitation vs. complete reconstruction
- bridge rehabilitation vs. replacement
- lane addition
- facility upgrade
- increased capacity (using new technology)

These types of projects can be assessed at the level of a single roadway segment or at the network level. Inputs necessary to run the model include roadway physical characteristics (number of lanes, road grade, pavement surface characteristics, traffic capacity), operational characteristics (traffic volume and speed, vehicle composition, peaking characteristics), and project characteristics (construction costs, right-of-way costs, maintenance costs, and project schedule).

StratBENCOST compares project costs to the user benefits of transportation investments. Costs can include:

- *Project construction costs* – the costs of materials and labor used in building a project, including context sensitive design elements and environmental impacts mitigation
- *Project right-of-way costs* – the costs associated with obtaining land for a construction project
- *Other project costs* – items as performance bond costs, insurance, and legal fees not related to right of way acquisition or engineering costs
- *On-going maintenance costs* – items as minor pot hole repair, bridge, railing and culvert repairs, signage, fences, speed enforcement, snow removal, and administrative costs associated with operating a roadway over the 20-year facility design life
- *On-going life-cycle costs* – costs associated with periodic resurfacing and rehabilitation

User benefits (and disbenefits) are experienced directly by system users as a consequence of the improvement. They can include changes in travel time, operating costs, and safety.

- *Travel time changes* – projects that reduce roadway congestion or allow higher speeds will reduce travel time. The value of this benefit is calculated by applying the time savings to a monetary estimate of the traveler’s value of time.
- *Vehicle operating cost changes* – these may include changes to vehicle wear-and-tear or fuel consumption due to speed, route, and pavement surface changes. In many cases an improvement will allow higher speeds, which reduces fuel economy and increases vehicle operating costs. These higher costs may be offset by reduced vehicle wear as a result of pavement surface improvements.
- *Safety changes* – a project may change the number of vehicle crashes. Safety cost components include the cost of fatalities, injuries, and vehicle damage. Typically a “willingness to pay” approach is used to determine the dollar value of these benefits.

Note that there may also be benefits (or disbenefits) associated with vehicle air pollution emissions. This analysis has not estimated emissions costs because the study region does not include any area designated

[1] StratBENCOST was developed under National Cooperative Highway Research Program (NCHRP) Project 2-18(3) and is available from the Transportation Research Board.

as non-attainment with respect to EPA's national ambient air quality standards, and also because vehicle speeds do not vary significantly across the alternatives, so changes in emissions would be negligible.

Since benefits and costs often occur at different times over the lifespan of a project, they must be adjusted according to when they occur. Due to the time cost of money and the value placed on immediate consumption, future benefits and costs are worth less than those incurred immediately. To account for this, future benefits and costs are discounted and then summed to arrive at a present value. A project decision is then made by comparing the present value of the discounted stream of benefits to the present value of the discounted stream of costs.

Key Model Parameters

Several key parameters govern the benefit-cost analysis and must be specified at the outset in the StratBENCOST model.

- *Project period* specifies the time required for construction of a project alternative. In this analysis, Alternatives 1 and 2 (Improved Two-Lane and Improved Two-Lane with Passing Lanes) are assumed to have a project period of four years, and Alternatives 3 and 4 (Undivided Four-Lane and Divided Four-Lane) are assumed to have a project period of five years. The reality of funding constraints or other limitations may result in a longer construction period, particularly for the four-lane alternatives.
- *Period of analysis* specifies the number of years over which annual costs and benefits are calculated. The period of analysis includes both the project period (construction phase) and the design life of the facility. In this analysis, most project costs are associated with construction and will occur in the first few years of the analysis period, and benefits begin to accrue only after the improvement is complete and available to users. An analysis period of 25 years was used, after which the facility is assumed to require reconstruction or major rehabilitation. This is based on a 20-year facility design life and a four- or five-year construction period. For the purposes of consistency, a 25-year period of analysis was used for all alternatives.
- *Discount rate* is the rate at which future benefits and costs are reduced. The higher the discount rate, the greater the reduction in future benefits and costs. The discount rate is selected to reflect the opportunity cost of capital, which is the before-tax rate of return to incremental private investment. The future benefits and costs in StratBENCOST are given in *real* terms (i.e., they do not reflect inflation), so a *real* discount rate [2] was used. A discount rate of 4 percent was selected, based on discussions with MDT and reflecting historic trends in 10-year Treasure note yields.[3]
- *Traffic variables* were provided by David Evans and Associates, Inc. and are consistent with the Preliminary Traffic Engineering and Geometrics Report. In particular, the initial year average annual daily traffic (AADT) is 2,805, the annual change in AADT is 1.5 percent, and trucks and buses make up 9.5 percent and 0.7 percent of AADT, respectively.

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[2] In other words, the costs in the StratBENCOST model do not increase with inflation. The purpose of discounting in benefit-cost analysis is to convert costs and benefits in different years to values that are in comparable terms. If the model costs did rise with inflation, then the discount rate would need to be higher in order to factor in the rate of inflation as well as the rate of return to investment. Because the model costs do not rise with inflation, the discount rate does not include an inflation component.

[3] *Life-Cycle Cost Analysis in Pavement Design*, Federal Highway Administration, September 1998; and OMB Circular A-94.

Costs

Table 1 shows project costs and on-going costs associated with each alternative.[4] Project costs are one-time costs, and are assumed to be spread evenly over the project period. The construction period for the 2-lane alternatives is four years; the construction period for the 4-lane alternatives is five years. On-going costs occur every year during the analysis period, except during construction. The No-Build Alternative has no project costs but does have maintenance and lifecycle costs. Maintenance and lifecycle costs generally increase with the size (width) of each alternative.

Table 1: Project Costs and On-going Costs (in millions of 2003 dollars)

	No Build	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Project Costs (one time)					
Construction	-	62.9	66.4	85.1	95.4
Right of Way	-	2.4	2.4	3.5	4.8
Other	-	4.4	4.6	5.9	6.6
On-going Costs (per year)					
Maintenance	0.15	0.24	0.30	0.47	0.52
Lifecycle	0.8	1.4	1.7	3.5	4.0

Note: Estimated construction costs are substantially less than presented in earlier draft work products. The initial estimates were based on highly conservative unit costs compounded with a conservative estimate of contingencies for non-itemized items and unknown design/implementation issues. The costs now presented in this table are based on a more refined design, with unit costs adjusted to northern Montana historic bid prices.

Table 2 illustrates the effect of discounting future costs to arrive at a present value. As described above, in a benefit-cost analysis framework, future benefits and costs are discounted to reflect the time cost of money and allow comparison of benefits and costs that occur at different points in time. Streams of benefits and costs are discounted and summed to arrive at a present value. In Table 2 below, the first line shows the total project costs, which is the sum of the construction, right of way, and other costs shown in Table 1. The construction costs are spread over four or five years to reflect the construction period. The next line shows the present value of those project costs when discounted at a rate of 4 percent annually.

The third line in Table 2 below shows the on-going costs (maintenance and lifecycle costs, as shown in Table 1) for the period of analysis. As described above, for the no-build alternative, the on-going costs occur annually throughout the 25-year analysis period. For the build alternatives, the on-going costs occur annually after construction of the facility is complete. The fourth line in Table 2 shows the present value of the on-going costs when discounted at a rate of 4 percent annually. The next line shows the present value of the incremental on-going costs, or the difference between a build alternative and the no-build alternative. The last line shows the total costs associated with each alternative in present value terms, calculated by summing the present value of project costs and the present value of the incremental on-going costs. These present value costs are compared with project benefits later in this memo.

[4] "Construction, Maintenance, Lifecycle and Right of Way Costing Methodology – Inputs to Benefit Cost Analysis, Revised" memorandum from Steve Long, David Evans and Associates, Inc. to Karl Helvik, MDT, November 6, 2003.

Table 2: Summary of Costs and Present Value of Costs (in millions of 2003 dollars)

	No Build	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Total Project Costs (undiscounted)	0	69.7	73.4	94.5	106.8
Present Value of Project Costs (discounted)	0	65.8	69.3	87.5	98.9
Total On-going Costs (undiscounted)	23.8	34.4	42.0	79.4	90.4
Present Value of On-going Costs (discounted)	15.4	20.5	24.9	46.1	52.5
Present Value of Incremental On-going Costs (build minus no-build alternative) (discounted)	0	5.0	9.5	30.7	37.1
Present Value of Total Costs (discounted)	0	70.8	78.8	118.2	136.0

Benefits

Benefits are generated by reduced vehicle operating costs, fewer vehicle accidents, and a slight reduction in travel time. The StratBENCOST model is structured to calculate accident cost savings by making assumptions about the accident rate for a given facility type and traffic volume. The model is not structured to determine changes in accident rates for an improvement to a rural two-lane highway that does not modify the number of lanes. Therefore, in order to improve the accuracy of the calculations, accident benefits were determined outside the model, as described below, then combined with the other model-calculated benefits.

Table 3 shows the estimated rate of fatality, injury, and property damage only (PDO) accidents for each alternative. For the No-Build Alternative, the fatality, injury, and PDO accident rates were provided by MDT based on accident data for the US 2 study corridor for the period 1997 – 2001. For the build alternatives, the change in total accident rate was determined by David Evans and Associates, Inc. based on research documenting changes to safety and accident rates due to highway improvements,[5] adjusted to conditions specific to the US 2 corridor. These total accident rates were then disaggregated to the three accident types using the observed distribution in the US 2 study corridor for the period 1997 – 2001.

[5] *Safety Effects of the Conversion of Rural Two-Lane Roadways to Four-Lane Roadways*, Federal Highway Administration, November 1999; and *Prediction of the Expected Safety Performance of Rural Two-Lane Highways*, Federal Highway Administration, September 2000.

Table 3: Accident Rates by Type and Alternative (per million vehicle miles traveled (VMT))

Accident Type	No Build	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Fatality	0.0045	0.0041	0.0038	0.0037	0.0034
Injury	0.428	0.386	0.357	0.346	0.321
Property Damage Only	1.077	0.970	0.899	0.870	0.806
Total	1.51	1.36	1.26	1.22	1.13

The accident rates in Table 3 are applied to the segment VMT to determine the annual number of accidents. Annual accident costs are calculated using the following average per incident costs:[6]

- Fatality accident $3,000,000
- Injury accident $60,000
- Property damage only accident $2,300

The total accident costs for each alternative is calculated as follows:

S_j (Accident rate)$_j$ x (Yearly VMT) x (Accident costs by type of accident)$_j$

where j is defined as the type of accident.

Using the above formula, the total accident costs for each year and each alternative were calculated. The accident *benefits* for each alternative are calculated as the difference between the No-Build accident costs and the build alternative accident costs. This assumes that the accident benefits for each alternative will come into effect only after the construction of the project. Accident benefits change in each analysis year because of the growth in VMT. Table 4 shows, as an example, the accident benefits in year 5 (the first year of operation of the four-lane alternatives).

Table 4: Example of Annual Accident Benefits (Year 5, in millions of 2003 dollars)

	No Build	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Total Accident Costs	2.06	1.87	1.73	1.68	1.55
Accident Benefits	-	0.20	0.33	0.39	0.51

Note: In this table, benefits may not exactly equal the difference in accident costs due to rounding.

[6] Per accident costs by type were provided by MDT. The values are based on FHWA's October 31, 1994 Technical Advisory, "Motor Vehicle Accident Costs," and updated by FHWA based on the GDP implicit price deflator. Note that the injury accident cost is an average of three types of injury accidents provided in the 1994 Technical Advisory, weighted to reflect Montana historic crash data.

The annual accident benefits are discounted over the analysis period to arrive at the present value of benefits for each build alternative, shown in Table 5. These benefits are combined with other benefits, determined using the StratBENCOST model. The two other categories of benefits are vehicle operating cost savings and travel time savings.

Vehicle operating costs change due to a change in pavement surface condition (which affects tire wear, other vehicle maintenance costs, and fuel consumption) and a change in travel speed (which affects fuel consumption). Under all alternatives, the pavement surface is assumed to deteriorate until the roadway is resurfaced. We use the StratBENCOST model default pavement deterioration rate for all alternatives. This analysis utilizes an index of 1 to 5, with 1 the poorest pavement surface condition and 5 the best condition. The No-Build Alternative is assumed to have a current pavement surface index of 3 and receive resurfacing at years 5 and 15 of the analysis period, at which point the pavement surface index becomes 4. The build alternatives are assumed to have a pavement surface index of 5 upon construction and receive resurfacing every 10 years after construction, at which point the pavement surface index becomes 5 again.

Table 5 shows the vehicle operating cost savings for each build alternative, discounted for each year of the analysis period and summed to arrive at a present value. The bulk of these benefits result from the improved pavement condition under the build alternatives. The operating cost benefits are slightly lower for the four-lane alternatives because these alternatives allow slightly higher speeds, which reduces fuel economy and increases operating costs.

Travel time savings are calculated based on the relationship between traffic volume and roadway capacity. Because the study segment operates at a high level of service under the No-Build Alternative, the travel time savings under the build alternatives are small. StratBENCOST calculates travel time savings using a value of time of $12 per hour for passenger vehicles, $32 per hour for trucks, and $83 per hour for buses. Table 5 shows the travel time savings and total benefits by build alternative. Note that because only a small portion of total benefits are generated as a result of travel time savings, the comparison of total benefits to costs (described in the next section) is generally not sensitive to the value of time figures described above.

Table 5: Present Value of Benefits by Build Alternative Over 25 Years (in millions of 2003 dollars)

	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Accident Cost Savings	2.7	4.5	5.1	6.5
Vehicle Operating Cost Savings	35.0	34.8	30.4	30.4
Travel Time Savings	0	1.2	6.1	6.4
Total Benefits	37.6	40.5	41.7	43.3

Notes: The No-Build alternative, not shown in this table, has zero benefits under the benefit-cost analysis framework because benefits are defined as the difference between a build and no-build alternative. Due to rounding, the benefits in this table may not sum to the total.

Note that the StratBENCOST model can report results in probabilistic terms to help assess the likelihood of output values that have uncertainty. The values reported throughout this memo are the mean (most likely) values. Using this function, the model suggests a 90 percent probability that the benefits will fall in the following ranges (millions of 2003 dollars):

- Vehicle Operating Cost Savings, 2-lane alternatives: 24.7 – 46.1
- Vehicle Operating Cost Savings, 4-lane alternatives: 21.3 – 40.8
- Travel Time Savings, 2-lane alternatives: 0 – 1.9
- Travel Time Savings, 4-lane alternatives: 5.0 – 9.9

Probabilistic results are unavailable for the accident benefits because they are calculated outside the model.

Summary of Benefits and Costs

Table 6 shows the present value of total benefits and costs. All build alternatives result in a negative net benefit (benefit less cost). Benefits are approximately half of the costs of the two-lane alternatives and approximately one-third of the costs of the four-lane alternatives. If, due to funding limitations or other constraints, the construction period extends beyond the four or five year minimum period analyzed (without a change in total construction costs), then the present value of the total costs would decrease slightly, although costs would still exceed the benefits.

The No-Build Alternative (not shown in Table 6) has zero benefits and zero costs under a benefit-cost analysis framework.[7] Thus, the no build alternative has the highest net benefit (zero) among all alternatives.

The benefits increase slightly with each build alternative but generally show little variation across alternatives. Total benefits under the 4-Lane Divided are only 15 percent higher than the benefits under the Improved 2-Lane. This reflects the fact that the segment carries relatively low traffic volumes and the accident rates and travel times do not vary greatly across build alternatives.

Project costs increase significantly across the build alternatives. The total costs (present value) of the two 2-lane alternatives are relatively close (11 percent difference). However, the costs of the 4-Lane Undivided and 4-Lane Divided alternatives are 67 percent and 92 percent higher than the Improved 2-Lane alternative, respectively.

[7] Note that the analysis does account for the maintenance and lifecycle costs associated with the no build alternative. But for comparison purposes, the benefit-cost analysis defines total costs as the difference between a build alternative and the no build alternative. In that context, the no build alternative has zero costs.

Table 6: Summary of Benefits and Costs by Build Alternative Over 25 Years (in millions of 2003 dollars)

	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Total Benefits (present value)	37.6	40.5	41.7	43.3
Total Costs (present value)	70.8	78.8	118.2	136.0
Net Benefits (present value)	-33.2	-38.3	-76.5	-92.7
Benefit Cost Ratio	0.53	0.51	0.35	0.32

Notes: The No-Build Alternative, not shown in this table, has zero benefits under the benefit-cost analysis framework because benefits are defined as the difference between a build and no-build alternative. Due to rounding, the benefits in this table may not sum to the total.

These results are not surprising for a project that would improve a rural highway with relatively low traffic volumes, high level of service, and no extraordinary safety problems. Typically, most of the benefits from highway widening projects accrue as a result of a reduction in congestion and travel time. Because the build alternatives would have little effect on overall average travel time, the total benefits are relatively small, and are substantially outweighed by the costs of improving a 72.2 km (44.9-mile) highway segment.

Sensitivity Analysis

Although benefit-cost analysis is a widely used technique, it is not without limitations. Because the true cost of fatalities and injuries cannot be reduced to a monetary figure, the model relies on simplifying assumptions in order to qualify the benefits of nonmarketable goods, such as the value of life. Like all analyses, its output is only as accurate as the input data. Large differences in input values could produce substantially different results.

In order to gauge the sensitivity of the benefit-cost analysis results to input values, benefits were calculated using higher traffic growth rates. This allows an estimation of the amount of vehicle traffic that would be needed in order for benefits to exceed costs. Table 7 shows benefits, costs, and net benefits if study segment average annual daily traffic (AADT) grows at a rate twice that assumed in the Preliminary Traffic Engineering and Geometrics Report (3 percent growth rather than 1.5 percent). Note that this is an unlikely scenario, given the historic traffic growth rate in the corridor. Accident benefits and vehicle operating costs savings in this scenario are approximately 20 to 25 percent higher; travel time savings are approximately 60 to 65 percent higher. Total project costs are still significantly more than benefits under all four build alternatives.

Table 7: Sensitivity Analysis – Summary of Benefits and Costs With 3% AADT Growth Rate (in millions of 2003 dollars)

	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Accident Cost Savings	3.2	5.5	6.0	8.0
Vehicle Operating Cost Savings	43.1	42.8	37.7	37.6
Travel Time Savings	0	2.0	10.1	10.4
Total Benefits (present value)	46.3	50.3	53.8	56.0
Total Costs (present value)	70.8	78.8	118.2	136.0
Net Benefits (present value)	-24.5	-28.5	-64.4	-79.9
Benefit-Cost Ratio	0.65	0.64	0.46	0.41

Notes: The No-Build Alternative, not shown in this table, has zero benefits under the benefit-cost analysis framework because benefits are defined as the difference between a build and no-build alternative. Due to rounding, the benefits in this table may not sum to the total.

Table 8 shows benefits, costs, and net benefits if study segment AADT grows at a rate four times that assumed in the Preliminary Traffic Engineering and Geometrics Report (6 percent growth rather than 1.5 percent). Note that this is a highly unlikely scenario, given the historic rate of traffic growth in the corridor. Accident benefits and vehicle operating costs savings in this scenario are approximately 80 to 90 percent higher; travel time savings are four to five times higher. In this scenario, total project benefits equal the costs for the two 2-lane alternatives. Costs still outweigh benefits under the 4-lane alternatives. Thus, this sensitivity analysis suggests that the traffic growth rate must be on the order of four times higher than the baseline assumption in order for any build alternative to produce positive net benefits.

Table 8: Sensitivity Analysis – Summary of Benefits and Costs With 6% AADT Growth Rate (in millions of 2003 dollars)

	Improved 2-Lane	Improved 2-Lane with Passing Lanes	4-Lane Undivided	4-Lane Divided
Accident Cost Savings	4.9	8.3	9.2	12.2
Vehicle Operating Cost Savings	66.2	65.7	57.8	57.6
Travel Time Savings	0.0	5.4	28.7	29.6
Total Benefits	71.1	79.3	95.6	99.4
Total Costs (present value)	70.8	78.8	118.2	136.0
Net Benefits (present value)	0.3	0.5	-22.6	-36.6
Benefit-Cost Ratio	1.00	1.01	0.81	0.73

Notes: The No-Build Alternative, not shown in this table, has zero benefits under the benefit-cost analysis framework because benefits are defined as the difference between a build and no-build alternative. Due to rounding, the benefits in this table may not sum to the total.